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Electricity intensities of the OECD and South Africa: A comparison

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ABSTRACT

This paper investigates the relationship between South Africa's total electricity intensity and that of the OECD members, a very important trade block. These results will assist in ascertaining possible scope for improvement, if such exists. This is necessary as electricity is an essential input for production, and hence it affects the competitiveness of the country.

Calculating the electricity intensities, defined as the ratio of electricity consumption to total output, we found that South Africa's electricity intensity has more than doubled between 1990 and 2007. All the OECD members' (excluding Iceland) weighted growth in electricity intensity was lower than that of South Africa by a considerable margin. The sectoral analysis showed that the majority of the South African sectors are more electricity intensive.

To improve its industrial competitiveness and, as an additional benefit, contribute towards achieving its stated commitments towards reduction of greenhouse gas emissions, South Africa will have to improve its total and sectoral electricity efficiency levels, that not only were higher but also increasing at an alarming rate.

Contents

1. Introduction

Improving the electricity efficiency of a country is an important step towards decreasing greenhouse gas emissions originating from fossil fuel-based electricity generation and consumption. Studying the intensity of electricity usage (the quantitative measure of electricity efficiency) is important from an electricity/energy policy-making perspective since it is a measure that combines the electricity consumption with the economic output [1]. It is equally imperative for the authorities to understand how electricity demand will change under conditions of structural change in the economy [2].

In the past, a large number of studies were conducted to identify the dynamics, determinants and characteristics of electricity intensity in both developed and developing economies [3–6]. From these studies it is derived that electricity intensity first

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increases as a consequence of rising economic growth and development, but subsequently falls as a result of a shift to a services-based economic structure [7]. This trend can be compared to the famous environmental Kuznets curve [8,9] and applied to electricity intensity. A general policy objective is to "tunnel through" the curve and, hence, the need to compare one's own position relative to the objective, i.e. the downward trending side of the graph. This is to be followed by policies to achieve such tunnelling.

In this paper we seek to answer the question whether South Africa follows the international trends regarding electricity intensity. We do this by conducting a comparison between South Africa's national and sectoral electricity intensities and the equivalents thereof of the member countries of Organisation for Economic Co-operation and Development (OECD), main trading partners with South Africa. The main reason for focusing on the electricity intensity and not on energy in general is the fact that the energy sector is too diverse for a comparative analysis. For instance, the intensity trends in the use of petrol are dependent on whether the country in question is an oil-producer or not. However, both the OECD members and the South African electricity sectors present similarities, especially regarding their electricity generation which is regulated and controlled by monopolies. Hence, we argue that energy in general would not be a comparative indicator within the selected groups of countries.

While this exercise will indicate whether there is any scope for improvement on a national level from a South African perspective, it will also do so on a disaggregated sectoral level for at least two reasons. First, the economic sectors of a country have dissimilar economic and energy characteristics and it is therefore important to understand these differences [10]. Second, not all the economies produce the same basket of goods in the same proportion. Hence, there is a need to examine the country's electricity intensity profiles on a sectoral level to be able to make comparisons as well as use examples of successful case studies [11].

The next section of this paper will introduce the meaning of electricity efficiency and intensity as well as the current situation of electricity efficiency in South Africa. This is followed by the description of the data used and an international electricity intensity comparison on both a national and a disaggregated sectoral level. Finally, we conclude with a discussion of the findings.

2. Background

2.1. Electricity efficiency and intensity

The definition of electricity (or energy) efficiency seems to be complex and depends largely on the context within which the term is being used.[1] An economist, a politician and a sociologist may all have different definitions for such efficiency measures. When the Energy Information Administration (EIA) [12] asked participants in workshops to define "energy efficiency", the answers varied ranging from a service to a mechanistic perspective. The World Energy Council [13], however, provides the following guiding definition:

> *Energy efficiency improvements refer to a reduction in the energy used for a given service (heating, lighting,* etc.*) or level of activity. The reduction in the energy consumption is usually associated with technological changes, but not always since it can also result from better organisation and management or improved economic conditions in the sector ("non-technical factors").*

The importance of electricity efficiency cannot be overstated. Policies to this effect have globally been accepted as one of the most economical ways towards the reduction or slowing down of the increasing energy demand as well as its cost and environmental effects. Repetto and Austin [14] further demonstrate the significance of electricity efficiency improvement for positive results not only in the energy sector and the environment, but also in the economy as a whole. In order to measure electricity efficiency, the EIA [12] proposes two methods. First, there is the so-called market-basket approach and, second, the comprehensive approach. The first approach refers to the estimation of the energy consumption for a set of electricity services based on their share in an index computed as the Index of Industrial Production. The second approach refers to the estimation of broader indicators that measure the after-effects of electricity efficiency changes.

In contrast to the above, Mukherjee [15] proposes an approach from a production theoretic perspective. His measurement models are found on the objectives of energy management and cost minimisation as well as the capacity output of the economy. The conceptual difficulty in the analysis of energy efficiency, according to Bosseboeuf et al. [16], is that the evaluation and progress thereof is made after the implementation of energy efficiency policies. There is therefore a temporal, and even spatial, decoupling of the policy and its implementation, and that which is measured and observed later on. This also complicates comparison among countries. Bosseboeuf et al. [16] therefore make an effort to focus on the convergence of energy efficiency indicators globally by classifying the indicators used in the literature as follows:

- *Macro-indicators versus micro-indicators*: Macro-indicators are linked with the economy in its entirety or its main sectors. From a micro-perspective, the indicators are concerned with the level of the main end-users such as companies or households.
- *Ratios versus quantities*: Ratios such as energy use per GDP or quantities such as variations in the demand for energy are both used in the literature.
- *Descriptive versus explanatory indicators*: The descriptive indicators explain the energy efficiency situation and progress, while the explanatory indicators describe the factors responsible for the evolution.

Following from the above, energy (read also electricity) efficiency is therefore often measured in terms of the change in energy intensity in an effort to describe more accurately its quantitative nature. Energy intensity, in turn, is defined as the ratio of energy consumption to a unit of measurement (e.g. floor space, households, number of workers, GDP per capita) [12]. In response to Freeman et al. [17], who critically assess the commonly used energy intensity indicators for analysis particularly of the industrial sector, Andrade-Silva and Guerra [5] argue that there are six possible ways of calculating the energy intensity. The existence of different measures is based on the definition of energy intensity as the energy consumption (numerator) divided by the production or economic activity (denominator) of the economy. Energy consumption can be measured according to its thermal equivalence (in joule), or in economic terms (price). Accordingly, the economic activity of a country can be measured as the value added, value of delivered goods (production value minus the value

[1] It should also be noted that, as indicated above, this manuscript focuses exclusively on electricity. In literature, however, the discussion about the method of determining electricity efficiency is often done under the umbrella of energy efficiency. Hence, when referring to energy efficiency, it is to follow the convention of establishing the way of estimating such, but here we apply it exclusively to electricity.

of inventories) or production value [5]. Therefore, the proposed measures, in accordance with Bor [18] are

1. Thermal equivalence/added value.
2. Thermal equivalence/value of delivered goods.
3. Thermal equivalence/production value.
4. Economic measure/added value.
5. Economic measure/value of delivered goods.
6. Economic measure/production value.

Andrade-Silva and Guerra [5] also state:

> *… even when the physical measures can be used at the desired levels (disaggregated and aggregated), the economic nature measures emerge more strongly within the upper aggregation levels. This feature leans on favouring the establishment of a standard consumption measure per national production unit such as the joule (J) per US$ of GDP.*

Based on this, we have decided to standardise the definition of electricity intensity for our analysis as follows:

$$Electricity\ intensity = \frac{electricity\ consumption}{output} \quad (1)$$

This is a common definition also used by Mukherjee [15], Choi and Ang [19], Sun and Ang [20] and Streimikiene et al. [21].

2.2. Electricity intensity: the South African case

Following the political transition in 1994, the new democratically elected South African government considered energy issues as of great importance for the economic development of the country. In the first *White Paper on Energy Policy* [22] energy efficiency was mentioned among the *cross-cutting issues*. More specifically for the industrial and commercial sectors, the government committed itself to the following:

- Promotion of energy efficiency awareness.
- Encouragement of the use of energy efficiency practices.
- Establishment of energy efficiency standards for commercial buildings.
- Monitoring the progress.

While progress on these was slow owing to pressing socio-economic and development considerations, the South African Department of Minerals and Energy released its first Energy Efficiency Strategy in 2005 [23]. The purpose of the Strategy was to provide a policy framework toward affordable energy for all and diminish the negative impacts of the extensive energy use in the country. Its national target for electricity efficiency was to improve efficiency by 12% by 2015. It is admitted in the document that this target can be questioned and challenged, but the target was set in the wake of the fact that the country was the seventh biggest emitter of greenhouse gases on a per capita basis [24], the national electricity intensity was almost twice the average of the OECD countries, and that efficiency improvements are a necessity. The strategy, however, had limited impact to date and is currently being revised. This is clearly illustrated in Fig. 1.

Fig. 1 shows the economy-wide electricity intensity and its growth for the period 1994–2006. Total electricity intensity showed a sharp upward trend until 2004. The period 2005–2006 was characterised by a notable decrease in the electricity intensity of 8.4%. This decline can be explained in two ways: first, the electricity prices increased by 182% from 2002 to 2003 [25] and it was highly impossible for the electricity consumers to react and change their behaviour in the short-run. Hence, the drop in electricity intensity (caused by a decrease in the electricity consumption) might be due to the lagged impact of the high rise in electricity prices. Second, from a policy perspective, the Energy Efficiency Strategy implemented in 2005 [23] might also be the cause of the small decrease in 2005–2006. Nevertheless, owing to a lack of data for the following years, it is not yet possible to determine whether this is a permanent change in the overall electricity intensity or it is only a temporary drop.

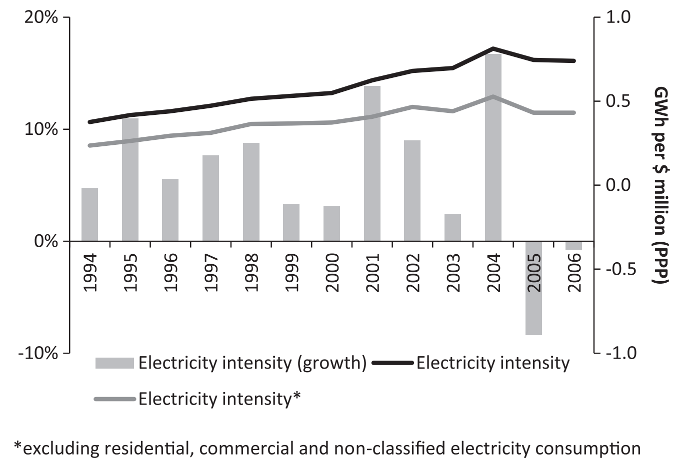


Fig. 1. Electricity intensity and its growth in South Africa: 1994–2006.
Sources: Authors' calculations based on IMF (2010) and OECD (2009b)

Table 1
Electricity intensity and output share per sector in South Africa: 2006.

Sectors	Electricity intensity GWh/$million (PPP adj.)	Ranking	Output share (%)	Ranking
Basic metals[a]	1.095	1	7.1	7
Mining and quarrying	0.634	2	14.6	2
Non-metallic minerals	0.524	3	1.6	12
Agriculture and forestry	0.316	4	6.0	8
Paper, pulp and printing	0.207	5	2.8	10
Chemical and petrochemical	0.203	6	16.3	1
Transport	0.089	7	12.5	3
Wood and wood products	0.069	8	1.4	13
Textile and leather	0.067	9	2.5	11
Food and tobacco	0.021	10	12.0	4
Machinery and equipment	0.005	11	2.9%	9
Transport equipment	0.003	12	9.8	6
Construction	0.002	13	10.5	5

[a] Includes 'iron and steel' and 'non-ferrous' metals.

However, if only the industrial, transport and agriculture sectors' electricity consumption is included in the calculation, a lower intensity is observed with the growth not being as steep as before. Large inter-sectoral variations, however, exist as can be seen in Table 1. In the first column, the sectors are ranked based on their electricity intensity levels in 2006 from the more intensive to the more efficient. This is compared to the sector's contribution or share to output and its relative ranking.

The three most electricity-intensive sectors in 2006 were 'basic metals' (which includes 'iron and steel' and 'non-ferrous metals'), 'mining and quarrying' and 'non-metallic minerals', while 'agriculture and forestry' was fourth in the ranking. The 'construction', 'transport equipment', 'machinery and equipment' and 'food and tobacco' sectors were the most electricity-efficient sectors of the economy. Various anomalies, however, exist when

comparing the relative size of the sector to its electricity efficiency. The largest sector, 'chemical and petrochemical', has the sixth highest intensity whereas 'basic metals', the most electricity-intense sector, is only seventh in size. 'Mining and quarrying', on the other hand, is second both in terms of size and intensity. Therefore, there clearly are inter-sectoral differences that can and should be subscribed to sectoral characteristics and that have to be taken into account when considering any electricity efficiency plan. Given this general information, how does South Africa compare both on a national as well as sectoral level, with the OECD countries? We turn to this next.

3. Research method and data

Several studies concerned with inter-country comparison of electricity intensities have been conducted [16,26,27]. However, these studies have encountered the following difficulties:

i) the heterogeneous definition of variables,
ii) the selected indicators to calculate electricity intensity (ratio: electricity consumption/economic output) differ from country to country,
iii) the diverse interpretations of the ratios calculated.

We tried to avoid these difficulties by estimating the electricity intensities for each country using the same definition (i.e. electricity consumption/gross domestic product (GDP)) and the same dataset. The group of OECD countries was selected for four distinct reasons: (a) among the OECD countries, there is a group (admittedly a small minority) of developing countries (according to IMF classification); (b) South Africa should be compared with international "best practice" in order to have the opportunity to learn and improve; (c) the country's major trading partners as well as trade competitors are included in the OECD panel, hence it is more appropriate for South Africa to be compared against their industrialisation levels and their sophisticated energy sectors, and; (d) South Africa has mixed characteristics resembling that of both developing and developed countries alike. This is also recognised by the Bureau of African Affairs [28] which argues that the country has a two-tiered economy: "…one rivalling other developed countries and the other with only the most basic infrastructure". The main aim, however, is not to be good among the developing countries, but to be good overall. Being compared with developed countries in energy matters is therefore appropriate given that South Africa's energy and industry sectors resembles that of the OECD.

Moreover, South Africa is one of the many non-member economies with which the OECD has working relationships in addition to its member countries [29]. The OECD Council at Ministerial level adopted a resolution in 2007 to strengthen the co-operation with South Africa through a programme of enhanced engagement. While enhanced engagement is distinct from accession to the OECD, it has the potential to lead to membership in the future. This makes South Africa a unique case of a developing economy that is not far from being considered a developed one.

Also, this group's data and definitions are consolidated under one umbrella organisation. This limits the risk of data inconsistencies. The data for electricity consumption (total and sectoral) were obtained from the OECD's *Energy balances for OECD countries* [30] and the data for South Africa was obtained from the *Energy balances for non-OECD countries* [31].

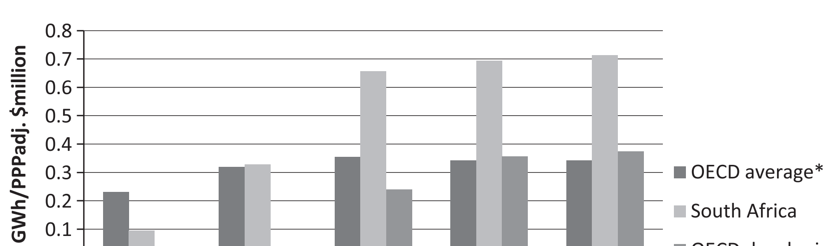
The national GDP data (in current prices) were derived from the *World Economic Outlook April 2010* of the International Monetary Fund (IMF) [32]. In order to achieve unilateral measurements of comparison avoiding thus local price and exchange rate fluctuations, we converted these figures firstly into real ones (extracting the price influences) by using the consumer price index (base year 2000, from IMF [32]) and subsequently, by employing the Power Purchasing Parity (PPP) adjusted real exchange rate values for all the countries (also from IMF [32]), we converted them all into GDP measured in US$, (as in Streimikiene et al. [33]). The disaggregated data for output for OECD members were derived from the STAN Database for Structural Analysis of OECD.

4. Comparative analysis

4.1. Comparing South Africa to OECD averages

In 1980 South Africa's electricity intensity was substantially lower than that of OECD countries (see Fig. 2). This is to be expected to some extent given the high level of welfare enjoyed by a minority of people based on an industrial sector that serviced only a few with limited focus on exports at that point in time. Given the country's skew income distribution, a skew electricity usage was also presented: the higher income sectors were the most electricity intensive too.

The country's electricity use rose since the early 1990s with the abolishment of sanctions, the internationalisation of the markets to international trade, and the more stable economic and political situation after the first democratic elections in 1994. With the economy open to international trade after 1994, the country's exports of electricity have also increased. In combination to the



	1980	1990	2000	2006	2007
OECD average*	0.2302	0.3184	0.3544	0.3418	0.3422
South Africa	0.0948	0.3291	0.6573	0.6935	0.7132
OECD developing	0.0105	0.0378	0.2406	0.3560	0.3742

* It excludes Czech Republic, Slovak Republic and Turkey due to lack of data for 1980 and 1990.

Fig. 2. Evolution of electricity intensity: OECD (average and developing) and South Africa.
Source: Authors' calculations based on IMF (2010) and OECD (2009a and 2009b)

slowly rising growth of the economy, the electricity use showed upwards trends and since the 1990s the electricity intensity in South Africa kept rising at an alarming rate. Currently it far exceeds that of the OECD countries with no sign of any change.

While the OECD countries kept their average electricity intensity relatively constant in the range of 0.34–0.35 GWh/$ million (PPP adj.) over the period 1990–2007, South Africa's electricity intensity almost doubled from 0.329 GWh/$ million (PPP adj.) in 1990 to 0.657 GWh/$ million (PPP adj.) in 2000 and increased even further to 0.694 GWh/$ million (PPP adj.) in 2006 and 0.713 GWh/$ million (PPP adj.) in 2007.

In Fig. 2, we also extracted the developing economies of the OECD group (i.e. Hungary, Poland, Mexico and Turkey) and compare their average against South Africa for a better view of the country's position against emerging economies. South Africa's electricity efficiency was significantly higher from 1980 to 2007 than that of the average of the OECD developing economies. Although they also showed a substantial increase from 1990 to 2000 (536.5%), the starting point in 1990 was significantly lower than that of South Africa.

4.2. South Africa and OECD member states: an economy-wide comparison

Following this analysis, we disaggregate the OECD average to examine how South Africa compares with the OECD countries individually over the study period. The economy-wide percentage change of electricity intensity for the period 1990–2007 as well as the electricity intensity of 2007 for the OECD members and South Africa is presented in Fig. 3(a). It should be noted that Poland, Hungary, Mexico and Turkey were outliers (hence, excluded from the figure) with changes in electricity intensity from 1990 to 2007 of 382%, 401%, 493% and more than 1000% (from 0.0006 in 1990 to 0.723 in 2007) respectively. Also, the Czech and Slovak Republics were excluded due to lack of data points for 1990. (For a comparison of only the OECD developing economies see Fig. 3(b).)

From Fig. 3(a) it is clear that South Africa has shown an increase in electricity intensity of 117% over the study period. This is in sharp contrast to the average of the OECD members (excluding Poland, Hungary, Mexico, Turkey, and the Slovak and Czech Republics), which showed an increase of only 10.09%. Only the Mediterranean countries (Spain, Greece, Portugal and Italy) as well as Korea and Iceland experienced an increase in their electricity intensities. Both their electricity consumption and output increased substantially, but the increase in consumption was higher than the growth in output and therefore their intensities experienced sharp increases. All the other countries' intensity levels declined over the study period indicating remarkable improvements in electricity efficiency.

From the same graph it can also be observed that there is a statistically significant negative, or inverse, relationship between the level of electricity intensity in 1990 and its growth over the study period (see Appendix for statistic results on the significance

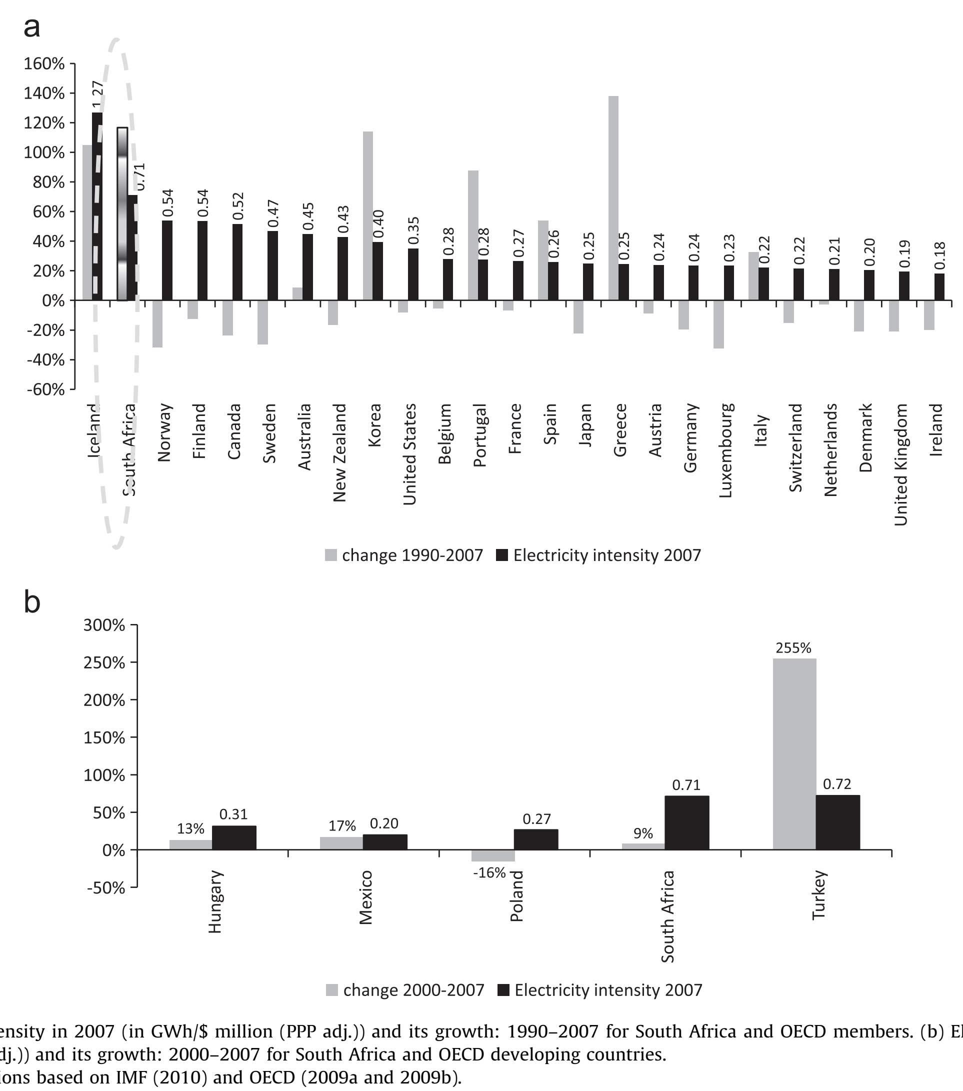


Fig. 3. (a) Electricity intensity in 2007 (in GWh/$ million (PPP adj.)) and its growth: 1990–2007 for South Africa and OECD members. (b) Electricity intensity in 2007 (in GWh/$million (PPP adj.)) and its growth: 2000–2007 for South Africa and OECD developing countries.
Source: Authors' calculations based on IMF (2010) and OECD (2009a and 2009b).

of the relationship). This implies that the higher the electricity intensity of a country in 1990, generally speaking, the more negative its growth was from 1990 to 2007. Countries such as Norway, Canada and Sweden, which were the most electricity intensive in 1990, were the ones that managed to decrease their intensity of electricity usage meaningfully, namely by 32%, 24% and 30% respectively. This is in contrast with Italy, Portugal and Greece, which had the lowest intensities in 1990, but the highest increases. South Africa, however, does not fit this trend well. It had an average electricity intensity in 1990 and yet it had the second highest increase (after Greece) of its intensity (117%).

Fig. 3(b) presents a rather dismal picture for South Africa's electricity intensity in comparison with the developing countries of the OECD. Its growth for the period 2000–2007 was significantly less than that of Turkey (255%) and less than Hungary and Mexico (13% and 17% respectively). However, Poland managed to reduce its electricity intensity by 16% for the same period. It is interesting to see that South Africa and Turkey had similar intensities in 2007 (0.71 and 0.72), but Turkey increased theirs sharply (255%) to "catch up" with the South African level. South Africa, therefore, does not follow international trends of developing economies in this regard either.

To determine the change in the country's relative position we calculated the weighted growth rate of each of the countries in order to take into account both the changes as well as the initial and final electricity intensity levels of the respective countries over the study period. We did this using Eq. (2) and normalising the answer so that South Africa's growth equals 1. The results are presented in Fig. 4.

$$weighted\ growth_i = \frac{electricity\ intensity_{i,2007}}{electricity\ intensity_{SA,2007}} \times real\ growth_i \quad (2)$$

where electricity intensity$_{i,2007}$ is the electricity intensity of country i in 2007; electricity intensity$_{SA,2007}$ is the electricity intensity of South Africa in 2007 and real growth i is the (positive or negative) growth of electricity intensity of country i from 1980 to 2007.

From Fig. 4 it can be seen that the only countries that did worse than South Africa were Iceland and the developing OECD countries (Hungary, Poland, Mexico and Turkey with the last being excluded from the graph as an outlier). All the other OECD members' (excluding the outliers) as discussed for Fig. 3(a) weighted growth were either positive, but lower than the South African (six out of twenty-eight countries), or negative (seventeen out of twenty-eight countries). The results from Figs. 3(a) and (b) and 4 clearly indicate that South Africa's electricity intensity was not only higher than the majority of OECD countries in absolute terms (for 2007), but also showed an excessive increase for the period 1990–2007, compared to the rest of the countries in the studied group. The next question that arises is whether this trend and big difference to OECD countries holds true for all the economic sectors of South Africa.

4.3. South Africa and OECD member states: a sectoral comparison

To investigate the differences among the industrial sectors, Table 2 presents the average sectoral electricity intensities for South Africa and the OECD in 2006 and their differences. The last column presents a weighted difference relative to the output shares of each sector and was calculated as follows:

$$Weighted\ difference_i = \frac{sector's\ output\ share_{OECDave}}{sector's\ output\ share_{SA}} \times difference_i \quad (3)$$

where sector's output share$_{OECDave}$ is the average output share of sector i in the OECD economies in 2006; sector's output share$_{SA}$ is the share of sector i in South Africa in 2006 and difference i is the percentage difference of electricity intensity between South Africa and the average of the OECD members in 2006.

The majority of the South African sectors were more electricity intensive than the OECD average. Only four out of thirteen sectors were more efficient than the OECD and they are 'construction', 'food and tobacco', 'machinery' and 'transport equipment'. The order of magnitude in which they outperformed their OECD counterparts was, on average, 150.5% (average of weighted differences). This is in stark contrast to the degree in which the OECD sectors outperformed the South African ones: on average 980.7% (average of weighted differences).

'Basic metals' have the highest electricity intensity in both South Africa and the OECD countries. Comparatively speaking, however, South Africa's 'basic metals' sector was significantly more intensive (886%) than the OECD average before adjusting it to its respective size (or contribution to output) (644%). The most efficient sector was 'construction', mainly owing to its high labour intensity and lower use of electricity-demanding technologies. On top of that the South African 'construction' sector was significantly more efficient than the OECD average. The reasons why the 'construction' sector was more efficient compared to the rest can only be speculated owing to a number of inter-linked factors—one

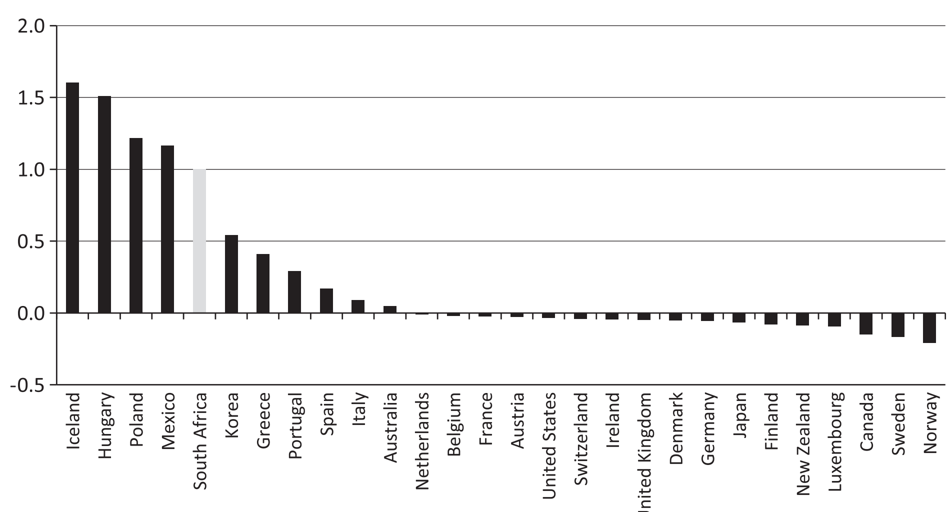


Fig. 4. Weighted electricity intensity growth relative to South Africa's electricity intensity where SA (2007)=1).
Source: Authors' calculations based on IMF (2010) and OECD (2009a and 2009b).

Table 2
Sectoral electricity intensities in 2006: South Africa and OECD.

Sectors	South Africa		OECD		Difference (%)	Weighted relative to output difference
	Electricity intensity	Output share (%)	Electricity intensity	Output share (%)		
Agriculture and forestry	0.316	6.0	0.016	4.0	1870.9	1242.4
Basic metals[a]	1.095	7.1	0.111	5.1	887.3	644.2
Chemical and petrochemical	0.203	16.3	0.034	15.2	494.7	462.9
Construction	0.002	10.5	0.087	16.6	−97.9	−155.9
Food and tobacco	0.021	12.0	0.023	8.3	−11.3	−7.8
Machinery	0.005	2.9	0.028	15.0	−81.2	−416.9
Mining and quarrying	0.634	14.6	0.026	3.0	2305.6	482.1
Non-metallic minerals	0.524	1.6	0.020	2.0	2517.7	3169.7
Paper, pulp and printing	0.207	2.8	0.021	5.5	891.5	1758.6
Textile and leather	0.067	2.5	0.010	1.9	548.8	398.3
Transport equipment	0.003	9.8	0.004	10.5	−20.1	−21.7
Transport sector	0.089	12.5	0.013	11.2	563.4	505.7
Wood and wood products	0.069	1.4	0.027	1.5	153.6	162.5

[a] Includes 'iron and steel' and 'non-ferrous metals'.

of them being the labour intensity of the sector. Also, all the South African sectors are more labour intensive in comparison with the OECD countries, especially 'construction', which is 600% higher than its OECD equivalents. The difference of the rest of the South African sectors to the OECD ones was in the range of 100–300%. The weighted difference shows that the South African intensity was 156% lower than the OECD average.

While the most electricity-intensive South African sectors (i.e. 'basic metals' and 'non-metallic minerals') present high differences compared to the OECD average (877% and 2517% and weighted differences of 644% and 3169% respectively), 'mining and quarrying' does not follow suit. The South African electricity intensity was 2305% higher than the OECD average. However, considering that the South African mining sector is a dominant one for the economy (14.6%) while it is a very small proportion of the OECD production (3%), the weighted difference is considerably lower (482%), albeit still very meaningful.

5. Discussion

It is evident from the above analysis that South Africa's electricity intensity was at a level much higher than that of the OECD countries and that the gap between South Africa and the OECD is also increasing at an alarming rate. While distressing, it also points towards the available scope for improvement. Not only is there scope, but improvement will also be necessary if South Africa is to remain competitive and trade with its OECD counterparts under the more stringent trade regimes, including carbon and climate change considerations, given that South Africa's electricity sector has a large carbon footprint [34,35].

South Africa has shown an increase in electricity intensity over the study period of 117%—more than doubling its electricity intensity from 0.32 to 0.71 GWh/$ million (PPP). This is in sharp contrast to the average of the OECD members (except Poland, Hungary, Mexico, Turkey, Slovakia and Czech Republic), which was only 10.09%. After weighing the growth by taking into account the different starting levels in 1990, it was evident that South Africa's performance was significantly worse than that of the OECD member states.

The economy-wide results show that South Africa is perhaps slowly reaching the level of development that would place it on the top of the environmental Kuznets curve with a positive but declining growth rate of efficiency. However it would be beneficial for South Africa to learn from countries with high efficiency rates and maybe aim to tunnel through the curve, reaching the "other (or downhill) side" of the curve faster.

Furthermore, reaching a certain development level or income growth is a necessary but not sufficient condition to improve the country's electricity efficiency levels. As Yandle et al. [36] argue the improvement of efficiency levels and the environment together with economic prosperity is not automatic but relies on appropriate policies and institutions. Hence, high-income economies that do have the necessary and appropriate policies in place are placed on their way down the Kuznets curve in contrast to South Africa.

In order to identify the possible differences between the economic sectors of the OECD members to those of South Africa, we examined the differences between the South African economic sectors' electricity intensities and their equivalent of the OECD countries. Nine out of thirteen South African sectors are more intensive than their OECD equivalents by a considerable margin. Although 'basic metals', 'mining and quarrying' and 'non-metallic minerals' were the most electricity-intensive sectors, they presented the greatest gap between South Africa and the OECD, with these sectors in the OECD being more efficient. It was also observed that the economic sectors' electricity efficiency behaviours are radically different. Therefore, a sector-specific approach is required to improve efficiency levels in South Africa.

Next is to identify possible reasons that led the South African electricity intensity to a worse position than the OECD members (both developed and developing). One possible reason might be the low and stable prices of electricity in the country for the studied period. South African producers were not concerned for electricity efficiency given the relatively low price levels of electricity over the period. Fig. 5 plots the average electricity prices in comparison with the total electricity intensity in South Africa for the period from 1993 to 2005.

Fig. 5 illustrates the existence of low and stable electricity prices over the period 1993–2002; while price restructures are responsible for the structural break in the years 2002 and 2003 where the prices increased by 182%. In contrast, the electricity intensity has been increasing since 1993 but with a decreasing rate, especially after the rise of the electricity prices. The period 2005–2006 was characterised by a notable decrease in the electricity intensity of 8.4% while the prices increased only by 3.5% in the same period. There are two possible reasons for this change. First, the electricity prices increased by 182% in 2003 and

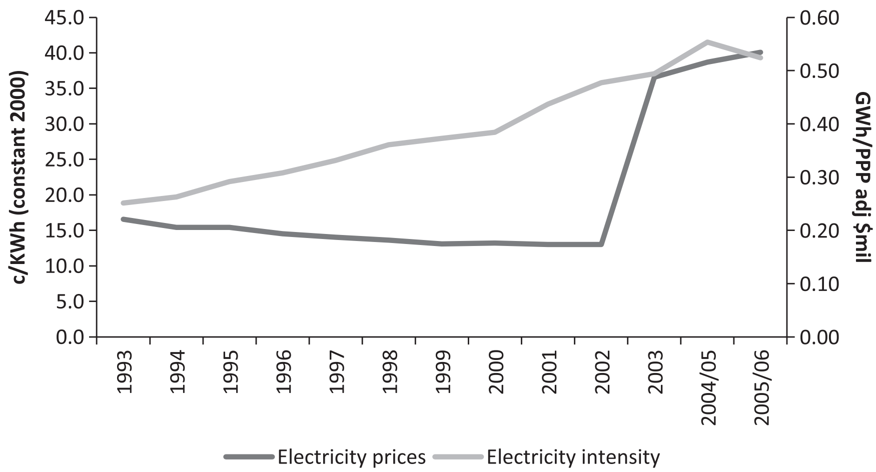


Fig. 5. Electricity intensity and electricity prices in South Africa: 1993–2005.
Source: DME (2009) and authors' calculations based on IMF (2010) and OECD (2009a and 2009b).

the drop in electricity intensity (caused by a decrease in electricity consumption) might be considered the lagged impact of the high increase in electricity prices.

Second, the South African Department of Minerals and Energy released its first Energy Efficiency Strategy in 2005 [25]. The purpose of this Strategy was to provide a policy framework toward affordable energy for all and diminish the negative consequences of the extensive energy use in the country. Its national target for electricity efficiency was to improve efficiency by 12% by 2015. From a policy perspective, this document might also be the cause of the decrease in 2005–2006. However, it did not have the desired effects to date and is currently being revised.

Other possible explanations might be associated to the lack of resources and incentives to use technologies and products that are not so intensive. Problems such as poverty and access to energy were higher in the priority list of the policy makers. Only recently there have been efforts from policy perspective to encourage improvements of energy efficiency. Eskom's Demand-Side Management (DSM) programme is among them. This type of programmes might also be the reason why the electricity intensity's growth rate started decreasing recently (Fig. 1). Finally, the loss of 1800 MW worth of generating capacity in the Western Cape and subsequent wide-spread blackouts in that area during 2006 have contributed to the fact that less electricity was consumed in the country.

6. Conclusion

The study of the efficiency of electricity use has recently become an important topic owing to the linkage of high electricity consumption with the negative consequences of greenhouse gas emissions. The energy policy-makers should take into account the electricity efficiency of the economy because it is a measure that combines the electricity consumption with the economic output [1].

South Africa's electricity intensity more than doubled from 1990 to 2007 (from 0.329 to 0.713) and the country's weighted growth was higher than the majority of the OECD members by a considerable margin. In addition, nine out of thirteen South African economic sectors are more intensive than their OECD counterparts.

It therefore became apparent that for South Africa to reduce its electricity intensity, it has to either reduce its electricity usage or increase its production while keeping its electricity consumption stable. This can be done through a concerted industrial policy to enhance the use and development of electricity efficient appliances. Electricity price reform, such as what has recently been announced, whereby the electricity price level is significantly increased in conjunction with block rate tariffs which charges a higher rate to those that consume more, is also vital. A nationwide demand-side management programme is also essential in the wake of these results in order to improve efficiencies.

Table A1
Summary of statistic tests pertaining to the trend in electricity intensity and its growth rate.

Test	Chi-square	Bartlett chi-square
Statistic	3.63	3.41
***p*-value**	0.057	0.065
Conclusion	Statistically significant	Statistically significant

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Appendix

See Table A1.

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